OPIC
OFFICE DE LA PROPRIÉTÉ INTELLECTUELLE DU CANADA

CIPO
CANADIAN INTELLECTUAL PROPERTY OFFICE

(12) (19) (CA) **Demande-Application**

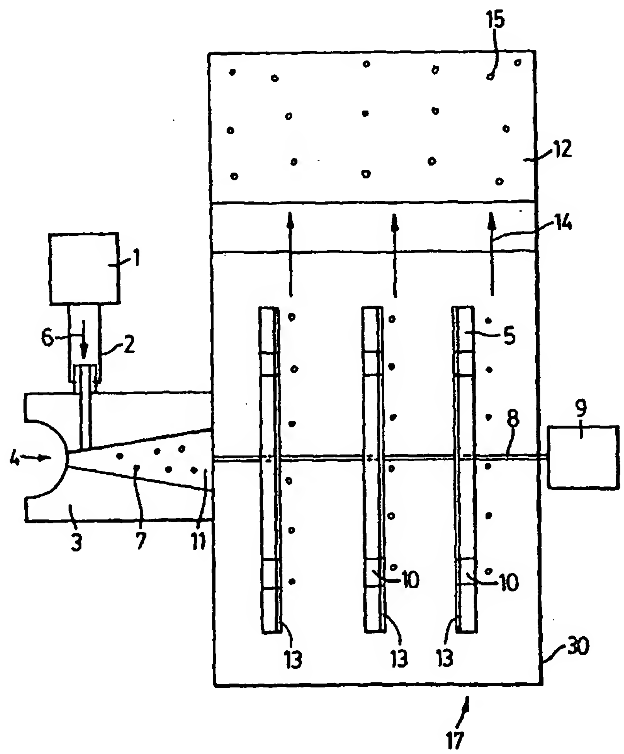
(21) (A1) **2,288,544**
(22) 1999/11/04
(43) 2000/05/09

(72) CONRAD, WAYNE ERNEST, CA
(72) CONRAD, HELMUT GERHARD, CA
(72) SZYLOWIEC, TED, CA
(71) FANTOM TECHNOLOGIES INC., CA

(51) Int.Cl.[6] B01F 3/04
(30) 1998/11/09 (2,253,101) CA
(30) 1999/02/01 (09/240,617) US

(54) **METHODE ET APPAREIL POUR AUGMENTER LA DISSOLUTION D'UN FLUIDE DANS UN AUTRE FLUIDE**

(54) **METHOD AND APPARATUS FOR ENHANCING THE DISSOLUTION OF ONE FLUID IN ANOTHER FLUID**



(57) A process for compressing a liquid and a gas comprises introducing at least one gas and at least one liquid into a prandtl layer turbine and passing the gas and the liquid through the prandtl layer turbine to obtain a liquid/gas mixture. The gas/liquid mixture may then be a reduced pressure to form microbubbles.

Industrie Canada Industry Canada

Title: METHOD AND APPARATUS FOR ENHANCING THE DISSOLUTION OF ONE FLUID IN ANOTHER FLUID

FIELD OF THE INVENTION

This invention relates of a method for dissolving a gas into a liquid. The device may also be used to mix together two or more gasses or two or more liquids. The gas may be present either by itself or in combination with one or more other gasses and/or a liquid. Further, the liquid into which the gas is to be dissolved may be present by itself or may also have one or more liquids and/or one or more other gases associated therewith.

BACKGROUND OF THE INVENTION

In many applications, it is desirable to dissolve a gas into a liquid. Various different apparatus have been developed in the past for dissolving gases into liquids. Examples of such techniques include the use of a sparger, venturi or other inlet devices for introducing gas bubbles into a liquid which is held in a reactor. Another technique comprises passing a gas and a liquid in counter current flow through a packed tower. It has also been known to pass a liquid and a gas through a pump so as to intimately mix the liquid and the gas to obtain a gas liquid mixture.

One disadvantage of these techniques is that only a limited amount of the gas is dissolved or exposed to the liquid. Further, if a pump is used, only limited pressures may be exerted on the liquid/gas mixture in order to prevent cavitation. In order to obtain higher dissolution efficiencies, the process must be repeated. This may be achieved by recovering the undissolved gas and recycling it through the process.

BRIEF SUMMARY OF THE INVENTION

In accordance with the instant invention, there is provided a mixing apparatus comprising a housing; at least one

inlet port for introducing at least one gas and at least one liquid to the housing; a plurality of spaced apart members rotatably mounted within the housing; and, a drive member for rotating the spaced apart members at a rate sufficient for dissolving at least a portion of the gas into the liquid to form a liquid/gas mixture and at a rate sufficient to maintain a laminar flow in a boundary layer adjacent the spaced apart members.

One advantage of the instant invention is that, by the use of a prandtl layer pump, the liquid and gas may be subjected to high pressures (eg up to 250 psig) in a very compact space without risk of cavitation. With conventional pumps, it would be necessary to maintain a very large head pressure to prevent cavitation of the gas as it passes through the pump. With the use of a prandtl layer pump, it is possible to subject a gas to elevated pressures in the pump without the need of a matching head pressure. thus the pump may be used as a mixing apparatus at generally any location in a process.

Another advantage of the instant invention is that at the elevated pressures which may be achieved by using the method and apparatus of the instant invention, increased dissolution of the gas into the liquid may be achieved.

In one embodiment, the mixing apparatus also has as a pressure reduction zone downstream from the spaced apart members. The pressure to which the gas/liquid mixture is subjected is preferably rapidly reduced when the gas/liquid mixture enters the pressure reduction zone. The rapid pressure reduction allows at least some of the dissolved gas to come out of solution to form a fine dispersion of bubbles. Surprisingly, this rapid pressure reduction results in the gas forming a suspension of bubbles which may be ultra-fine (e.g. 1-5μ). These bubbles define an extended contact surface. For example, a bubble produced by a sparger

generally has a diameter of about 100 microns and has a surface area of about $3.1 \times 10^{-8} m^2$. A bubble when produced by this invention may have a surface area of 7.9×10^{-11} which is 2000 times greater.

The mixing apparatus may have a catalyst incorporated therein or introduced therein. Preferably, the catalyst is used in conjunction with the pressure reduction zone to take advantage of the extended contact surface which is created by the bubbles. A catalyst reactive with at least one of the gas and the liquid may be applied to at least a portion of one of the spaced apart members. Alternately, or in addition, a catalyst reactive with at least one of the gas and the liquid may be provided in the pressure reduction zone. The catalyst may be contained in the apparatus as a replaceable member or it may be introduced into the apparatus as part of the fluid stream, as a gas or a liquid or a solid but preferably in a liquid or a solid form.

In one particulary preferred embodiment, the at least one gas comprises ozone and the at least one liquid comprises water and the mixing apparatus is used in the treatment of water. This process takes advantage of the intimate contact which may be obtained by the method and apparatus of the instant invention to achieve a high level of disinfection in a relatively short period of time. Further, by using the pressure reduction zone, a high degree of reliability of the treatment is achieved due to the even distribution of ozone in the water which occurs when the bubbles are formed since the ozone is evolved from all portions of the water at the reduced pressure conditions.

In another embodiment, at least two gases are introduced through the inlet port and the at least one liquid is inert whereby the at least one liquid is a media for the dissolution of one of the gases into another of the gases or for the reaction of the gases with each other.

In another embodiment, the inlet port comprises at least two venturi, at least one gas being introduced through one of the venturi and the liquid being introduced through the other venturi.

In another embodiment, the inlet port includes a member for dividing the gas into bubbles in the fluid.

In accordance with the instant invention, there is also provided a mixing apparatus comprising means for creating a boundary layer adjacent a plurality of spaced apart members rotatably mounted within a housing; means for introducing at least one gas and at least one liquid to the housing; a plurality of spaced apart members rotatably mounted within the housing; and, means for rotating the spaced apart members at a rate sufficient for dissolving at least a portion of the gas into the liquid to form a liquid/gas mixture.

In one embodiment, the mixing apparatus further comprises means for rapidly depressurizing the gas/liquid mixture. The mixing apparatus may also comprise means for contacting the gas/liquid mixture with a catalyst reactive with at least one of the gas and the liquid when the pressure to which the gas/liquid mixture is subjected has been reduced.

In another embodiment, a catalyst reactive with at least one of the gas and the liquid is applied to at least a portion of one of the spaced apart members.

In another embodiment, the at least one gas comprises ozone and the at least one liquid comprises water and the mixing apparatus is used in the treatment of water.

In another embodiment, at least two gases are introduced into the housing and the at least one liquid is inert whereby the at least one liquid is a media for the dissolution of one

of the gases into another of the gases or for the reaction of the gases with each other.

In another embodiment, a catalyst is introduced into the mixing apparatus. The catalyst may be in a liquid or a solid form.

In another embodiment, the means for introducing at least one gas and at least one liquid to the housing comprises means for dividing the gas into bubbles in the fluid.

In accordance with the instant invention, there is also provided a method for mixing a liquid and a gas comprising introducing at least one gas and at least one liquid into a prandtl layer pump and passing the gas and the liquid through the prandtl layer pump to obtain a liquid/gas mixture.

In one embodiment, the method further comprises passing the liquid/gas mixture through a pressure reduction zone to obtain a liquid/gas mixture at a reduced pressure. Preferably, the pressure to which the gas/liquid mixture is subjected is preferably rapidly reduced.

In another embodiment, the method further comprises exposing at least one of the liquid and the gas to a catalyst in the housing.

In another embodiment, the method further comprises exposing at least one of the liquid and the gas to a catalyst in the pressure reduction zone.

In another embodiment, the at least one gas comprises ozone and the at least one liquid comprises water and the method comprises a process for the treatment of water.

In another embodiment, at least two gases are introduced through the inlet port and the method comprises a process for the dissolution of one of the gases into another of the gases or for the reaction of the gases with each other.

In another embodiment, the method further comprises introducing a catalyst into the mixing apparatus together with the at least one gas and the at least one liquid.

In another embodiment, the method further comprises separately introducing one of the at least one gas and the liquid into the housing.

In another embodiment, the method further comprises mixing the gas and the liquid to create gas bubbles in the liquid prior to introducing the liquid and the gas into the prandtl layer pump.

In accordance with the instant invention, there is also provided a method for mixing a liquid and a gas comprising the step of subjecting at least one gas and at least one liquid to an elevated pressure created at least in part by a plurality of rotating spaced apart members to obtain a liquid/gas mixture.

In one embodiment, the method further comprises the step of treating the liquid/gas mixture to obtain a solution containing microbubbles.

In another embodiment, the method further comprises the step of rapidly depressurizing the liquid/gas mixture.

In another embodiment, the method further comprises the step of reacting at least one of the liquid and the gas with a catalyst.

In another embodiment, the method further comprises the step of treating the solution with a catalyst.

In another embodiment, the at least one gas comprises ozone and the at least one liquid comprises water and the method comprises a process for the treatment of water.

In another embodiment, at least two gases are subjected to the elevated pressure conditions and the method comprises a process for the dissolution of one of the gases into another of the gases or for the reaction of the gases with each other.

In another embodiment, the method further comprises the step of introducing the catalyst into the rotating spaced apart members.

In another embodiment, the method further comprises the step of separately introducing one of the at least one gas and the liquid into the rotating spaced apart members.

In another embodiment, the method further comprises the step of introducing a mixture of gas bubbles in the liquid to the rotating spaced apart members.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other advantages of the instant invention may be more fully and particularly understood in connection with the following description of a preferred embodiment of the invention in which:

Figure 1 a schematic diagram of an apparatus according to the instant invention; and,

Figure 2 is an alternate embodiment of a schematic diagram of the apparatus of Figure 1.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The method and apparatus of the instant invention comprises the use of a prandtl layer turbine as a device for mixing fluids (eg. at least one gas with at least one other gas, at least one liquid with at least one other liquid, and preferably at least one gas with at least one liquid). Various embodiments of prandtl layer turbines have been developed over the years. Prandtl layer turbines comprise a plurality of rotatably mounted members (generally in the form of flat discs which are typically relatively thin) which are rotatably mounted in a housing. These devices are described in the United States Patent No. 1,061,206 (Tesla).

Various designs of such apparatus have been developed over the years but have generally not been employed commercially. The design described in Tesla may be used as a pump or as a motor. Such devices take advantage of the properties of a fluid when in contact with the rotating surface of the discs. If the discs are driven by the fluid, then as the fluid passes through the housing between the spaced discs, the movement of the fluid will cause the discs to rotate thereby generating power which may be transmitted via a shaft for use elsewhere. Accordingly, such devices function as a motor. Conversely, if the fluid in the housing is initially static, the rotation of the discs will cause the fluid in the housing to commence rotating in the same direction as the discs thereby causing the apparatus to function as a pump, drawing the fluid through the housing. In this application, all such devices are referred to herein as a "prandtl layer turbine".

Various designs for prandtl layer turbines have been developed. These include those disclosed in the United States Patent No. 4,402,647 (Effenberger), United States Patent No. 4,218,177 (Robel), United States Re-Issue Patent No. 28,742 (Rafferty et al.), United States Patent No. 5,470,197 (Cafarelli) and United States Patent No. 4,655,679 (Giacomel). The method and apparatus of the instant invention is applicable to all designs of a prandtl layer turbine.

In the preferred embodiment shown in Figure 1, fluid 4 and gas 6 are introduced into a housing 30, for example, by being drawn through a venturi 3 by means of a prandtl layer turbine 17. The prandtl layer turbine 17 consists of a series of plates (preferably discs) 5 which are non-rotatably mounted to a shaft 8 which is itself rotatably mounted in housing 30 such as by being connected to a motor 9 which provides the motive force to rotate the plates 5. The rotation of the plates 5 causes the fluid 4 to be drawn through the

venturi 3 which in turn causes a gas 6 to be drawn from the gas source 1 through tube 2 and into the venturi 3.

As shown in Figure 1, a single fluid stream is combined with the single gas stream which are fed via venturi 3 into prandtl layer turbine 17. It will be appreciated that gas 6 may comprise one or more gases (which may be combined with one or more liquids) and, similarly, fluid 4 may comprise one or more liquids (which may be combined with one or more gases). It will further be appreciated that the gases and the liquids may be separately introduced into prandtl layer turbine 17 into prandtl layer turbine 17.

Gas 6 and fluid 4 are preferably mixed prior to their introduction into prandtl layer turbine 17. More preferably, the gas 6 is preferably mixed with fluid 4 in such a manner as to form small gas bubbles 7 in the fluid flow stream. The bubbles may vary in size from about 50 to about 250 microns in diameter, more preferably from about 50μ to about 100μ and, most preferably, about 50μ. It will further be appreciated that various other devices besides venturi 3 may be used to create bubbles 7, such as a sparger. By creating a plurality of small gas bubbles 7 which are introduced into prandtl layer turbine 17, the surface area of gas 6 in fluid 4 which is introduced into prandtl layer turbine 17 is increased thereby increasing the dissolution which may be achieved of gas 6 into fluid 4 in prandtl layer turbine 17.

The gas laden fluid stream 11 is drawn through venturi 3 and into the spaced apart plates 5 such as via openings 10 in plates 5. As the fluid is forced outwards on a radial serpentine path along the rotating plates 5 the pressure of the fluid increases thereby increasing the dissolution of the gas 6 into the liquid 4. This increase in the pressure of the fluid is possible because, unlike conventional vane or centrifugal pumps, plates 5 in prandtl layer turbine 17 will

not be cavitated by the presence of the gas. The prandtl layer turbine may create a force of, for example, up to 100 psig and, more preferably up to 250 psig. The fluid with the gas dissolved therein may be sent to other apparatus for further processing.

Alternately, the pressurized liquid mixture 14 may be subjected to a reduced pressure. For example, the pressurized gas and liquid mixture 14 may be passed into an expansion zone 12 wherein the pressure to which the gas and liquid mixture 14 is subjected is reduced and preferably rapidly reduced. The liquid/gas mixture in the expansion zone may be at a pressure of, for example, 30-60 psig. This depressurization may occur in under 2 seconds, preferably under 1 second and, most preferably, is effectively instantaneous upon the liquid/gas mixture entering expansion zone 12. This depressurization allows the dissolved gas to come out of solution to form a suspension of ultra-fine bubbles 15. The bubbles may vary in size from about 1 to about 20 microns in diameter, more preferably from about 1 micron to about 5 microns and, most preferably, from 1μ to about 3μ. Due to the relatively fine nature of the bubbles, a large increase in the surface area of the gas is achieved. If the pressure reduction is conducted so as to achieve bubbles which are a few microns in diameter, then the number of bubbles which are achieved may be sufficiently high such that mixture 14 becomes translucent and, preferably, opaque. By varying the rate of pressure reduction and the amount of the pressure reduction, the size and the number of the bubbles may be adjusted.

This reduced pressure mixture may be used for various purposes. For example, the gas may include a compound which is reactive with a liquid. An example of this would be if gas 6 included or consisted of ozone and fluid 4 included or consisted essentially of water. In such a case, prandtl layer turbine 17 and expansion zone 12 may comprise an ozone chamber for treating (eg. disinfecting)

water. Alternately, the reduced pressure mixture may be used for treating another material (in such a case, fluid 4 may be an inert carrier). An example of this could be the use of the reduced pressure mixture as a treatment agent. For example, once again, if gas 6 was an oxidation agent (eg. ozone or peroxide), then the reduced pressure mixture may be fed to a tank containing a material (eg. a chemical compound such as a pesticide, a herbicide or metal) which is to be oxidized. In one preferred embodiment, the apparatus is for use in a domestic (i.e. residential) environment, eg. a house or a cottage, and the water to be treated may be from a municipal water supply which is fed to a house through supply pipes. It may also be water which is obtained from a well maintained by the individual or any other source that the individual has for their house or cottage.

It will also be appreciated that 2 or more gases may be fed into prandtl layer turbine 17. The gases may be reactive with each other and fluid 4 may optionally be inert. In such a case, the creation of the microbubbles creates an environment in which the gases may intimately mix and react with each other. It will be appreciated by those skilled in the art that other variations of the fluids which are introduced into prandtl layer turbine 17 may be used and that the reduced pressure mixture may be used for various purposes including from polishing a surface to electroplating operations.

It will further be appreciated that a catalyst may be added to the system. If one member of fluid stream 11 is to react with another portion of fluid stream 11, then the catalyst may be provided to enhance the reaction. The catalyst may be added to the system with fluid stream 11 or, alternately, it may be contained within turbine 17 or expansion zone 12. For example, the catalyst may be in the form of a solid, liquid or a gas and accordingly

introduced with either or both of gas 6 or fluid 4. Preferably, the catalyst is in the form of a liquid or a solid. The catalyst may be introduced with fluid 11 via venturi 3 or it may be introduced via a separate port into turbine 17. Plates 5 rotate so as to create a prandtl layer there adjacent. This prandtl layer creates a zone which effectively prevents solid particles from contacting plates 5. Accordingly, a prandtl layer turbine is particularly well adapted for receiving particulate matter, such as catalyst particles. By providing the catalyst as part of fluid stream 11, the catalyst is available for transportation downstream with mixture 14.

It will be appreciated that if the catalyst is used to assist in the reaction between members of fluid stream 11 (as opposed to a reaction involving a material positioned downstream of the apparatus) then the catalyst may be provided in various parts of turbine 17. For example, a catalyst layer 13 may be applied to the surface of plates 5 so as to enhance the reaction of constituents of fluid stream 11 with each other. Alternately, or in addition, the catalyst may be provided an expansion zone 12. Referring to Figure 2, a catalyst 16 may be placed as discreet particles 16 which are sufficiently large so as to be maintained in expansion zone 12 as mixture 14 passes there through. For example, expansion zone 12 may be provided with a pair of opposed mesh screens 24 with catalyst particles 16 positioned there between. Catalyst particles 16 and the openings in mesh 24 are sized so as to maintain catalyst particles in a fixed position in expansion zone 12. Alternately, catalyst particle 16 may be free floating in expansion zone 12. For example, the entry port and exit port to expansion zone 12 may be provided with mesh screens 25 and catalyst 26 may be positioned between screens 25 so as to be able to travel freely with expansion zone 12.

It will be appreciated that if fluid stream 11 is under a sufficiently great pressure as it enters parental layer turbine 17, that the fluid may assist motor 9 in rotating discs 5 or, alternately, turbine 17 may not include a motor 9 and, instead, fluid stream 11 may comprise the necessary motive force to cause plates 5 to rotate. Preferably, plates 5 rotate at an rpm from about 3000 to about 8000 more preferably from about 3000 to about 5000 and, most preferably, about 4000.

In the second embodiment shown in Figure 2, fluid 4 is drawn through venturi 3 and second venturi 20 by means of a prandtl layer turbine 17. The rotation of the plates 5 causes the fluid 4 to be drawn through venturi 3 and through venturi 20. This in turn causes the gas 6 to be drawn from the gas source 1 through tube 2 and into the venturi 3 and also causes the gas 19 to be drawn from the gas source 22 through the tube means 18 and into the venturi 20. The gases 6 and 19 are preferably drawn into the fluid 4 in such a manner to form small gas bubbles 7 and 21 to form in the respective streams of the fluid 4. The gas laden fluid stream 11 formed by the combination of the fluid from venturis 3 and 20, is drawn, for example, through openings 10 in the plates 5.

It will be appreciated that a gas may be introduced into the fluid passing through only one of venturis 3 and 20. Further, it will be appreciated that the fluid may pass through only a single venturi (eg. venturi 20) and the gas may be introduced separately (eg. through venturi 3) into prandtl layer turbine 17. It will be appreciated further that the gases 6 and 19 may be mixed together and both introduced simultaneously into fluid 4.

This design is particularly well adapted for use as a domestic water treatment apparatus. In particular, the apparatus may be ideally used as a point of entry water treatment unit (i.e. a water treatment unit which is designed to be affixed to the incoming

feed pipe to a house so as to treat at least a portion and preferably all of the water which enters a house). The unit may also be designed as a point of use water treatment apparatus (i.e., it may be connected to the cold water feed to a sink so as to treat all or at least a portion of the water which is fed to the sink and which may be dispensed to a separate supplemental faucet).

WE CLAIM

1. A mixing apparatus comprising:
(a) a housing;
(b) at least one inlet port for introducing at least one gas and at least one liquid to the housing;
(c) a plurality of spaced apart members rotatably mounted within the housing; and,
(d) a drive member for rotating the spaced apart members at a rate sufficient for dissolving at least a portion of the gas into the liquid to form a liquid/gas mixture and at a rate sufficient to maintain a laminar flow in a boundary layer adjacent the spaced apart members.

2. The mixing apparatus as claimed in claim 1 further comprising a pressure reduction zone downstream from the spaced apart members.

3. The mixing apparatus as claimed in claim 2 wherein the gas/liquid mixture is subjected to an elevated pressure in the housing and the pressure to which the gas/liquid mixture is subjected is rapidly reduced as it enters the pressure reduction zone.

4. The mixing apparatus as claimed in claim 1 wherein a catalyst reactive with at least one of the gas and the liquid is applied to at least a portion of one of the spaced apart members.

5. The mixing apparatus as claimed in claim 2 wherein a catalyst reactive with at least one of the gas and the liquid is provided in the pressure reduction zone.

6. The mixing apparatus as claimed in claim 1 wherein the at least one gas comprises ozone and the at least one liquid comprises water and the mixing apparatus is used in the treatment of water.

7. The mixing apparatus as claimed in claim 1 wherein at least two gases are introduced through the inlet port and the at least one liquid is inert whereby the at least one liquid is a media for the dissolution of one of the gases into another of the gases or for the reaction of the gases with each other.

8. The mixing apparatus as claimed in claim 1 wherein a catalyst is introduced into the mixing apparatus.

9. The mixing apparatus as claimed in claim 8 wherein the catalyst is a liquid or a solid form.

10. The mixing apparatus as claimed in claim 1 wherein the inlet port includes a member for dividing the gas into bubbles in the fluid.

11. The apparatus as claimed in claim 1 wherein the inlet port comprises at least two venturi, at least one gas being introduced through one of the venturi and the liquid being introduced through the other venturi.

12. The apparatus as claimed in claim 1 wherein the plurality of spaced apart members rotatably mounted within the housing are part of a prandtl layer turbine.

13. A mixing apparatus comprising:

(a) means for creating a boundary layer adjacent a plurality of spaced apart members rotatably mounted within a housing;

(b) means for introducing at least one gas and at least one liquid to the housing;

(c) a plurality of spaced apart members rotatably mounted within the housing; and,

(d) means for rotating the spaced apart members at a rate sufficient for dissolving at least a portion of the gas into the liquid to form a liquid/gas mixture.

14. The mixing apparatus as claimed in claim 13 further comprising means for rapidly depressurizing the gas/liquid mixture.

15. The mixing apparatus as claimed in claim 13 wherein a catalyst reactive with at least one of the gas and the liquid is applied to at least a portion of one of the spaced apart members.

16. The mixing apparatus as claimed in claim 14 further comprising means for contacting the gas/liquid mixture with a catalyst reactive with at least one of the gas and the liquid when the gas/liquid mixture has been subjected to a reduced pressure.

17. The mixing apparatus as claimed in claim 16 wherein the at least one gas comprises ozone and the at least one liquid comprises water and the mixing apparatus is used in the treatment of water.

18. The mixing apparatus as claimed in claim 13 wherein at least two gases are introduced into the housing and the at least one liquid is inert whereby the at least one liquid is a media for the dissolution of one of the gases into another of the gases or for the reaction of the gases with each other.

19. The mixing apparatus as claimed in claim 13 wherein a catalyst is introduced into the mixing apparatus.

20. The mixing apparatus as claimed in claim 19 wherein the catalyst is a liquid or a solid form.

21. The mixing apparatus as claimed in claim 13 wherein the means for introducing at least one gas and at least one liquid to the housing comprises means for dividing the gas into bubbles in the fluid.

22. A method for mixing a liquid and a gas comprising introducing at least one gas and at least one liquid into a prandtl layer turbine and passing the gas and the liquid through the prandtl layer turbine to obtain a liquid/gas mixture.

23. The method as claimed in claim 22 further comprising passing the liquid/gas mixture through a pressure reduction zone to obtain a liquid/gas mixture at a reduced pressure.

24. The method as claimed in claim 23 wherein the gas/liquid mixture is subjected to an elevated pressure in the turbine and the pressure to which the gas/liquid mixture is subjected is rapidly reduced.

25. The method as claimed in claim 22 further comprising exposing at least one of the liquid and the gas to a catalyst in the housing.

26. The method as claimed in claim 23 further comprising exposing at least one of the liquid and the gas to a catalyst in the pressure reduction zone.

27. The method as claimed in claim 22 wherein the at least one gas comprises ozone and the at least one liquid comprises water and the method comprises a process for the treatment of water.

28. The method as claimed in claim 22 wherein at least two gases are introduced through the inlet port and the method comprises a process for the dissolution of one of the gases into another of the gases or for the reaction of the gases with each other.

29. The method as claimed in claim 26 further comprising introducing a catalyst into the mixing apparatus together with the at least one gas and the at least one liquid.

30. The method as claimed in claim 22 further comprising separately introducing one of the at least one gas and the liquid into the housing.

31. The method as claimed in claim 22 further comprising mixing the gas and the liquid to create gas bubbles in the liquid prior to introducing the liquid and the gas into the prandtl layer turbine.

32. A method for mixing a liquid and a gas comprising the step of subjecting at least one gas and at least one liquid to an

elevated pressure created at least in part by a plurality of rotating spaced apart members to obtain a liquid/gas mixture.

33. The method as claimed in claim 32 further comprising the step of treating the liquid/gas mixture to obtain a solution containing microbubbles.

34. The method as claimed in claim 32 further comprising the step of rapidly depressurizing the liquid/gas mixture.

35. The method as claimed in claim 32 further comprising the step of reacting at least one of the liquid and the gas with a catalyst.

36. The method as claimed in claim 33 further comprising the step of treating the solution with a catalyst.

37. The method as claimed in claim 33 wherein the at least one gas comprises ozone and the at least one liquid comprises water and the method comprises a process for the treatment of water.

38. The method as claimed in claim 32 wherein at least two gases are subjected to the elevated pressure conditions and the method comprises a process for the dissolution of one of the gases into another of the gases or for the reaction of the gases with each other.

39. The method as claimed in claim 35 further comprising the step of introducing the catalyst into the rotating spaced apart members.

40. The method as claimed in claim 35 further comprising the step of separately introducing one of the at least one gas and the liquid into the rotating spaced apart members.

41. The method as claimed in claim 32 further comprising the step of introducing a mixture of gas bubbles in the liquid to the rotating spaced apart members.

ABSTRACT OF THE DISCLOSURE

A process for compressing a liquid and a gas comprises introducing at least one gas and at least one liquid into a prandtl layer turbine and passing the gas and the liquid through the prandtl layer turbine to obtain a liquid/gas mixture. The gas/liquid mixture may then be a reduced pressure to form microbubbles.

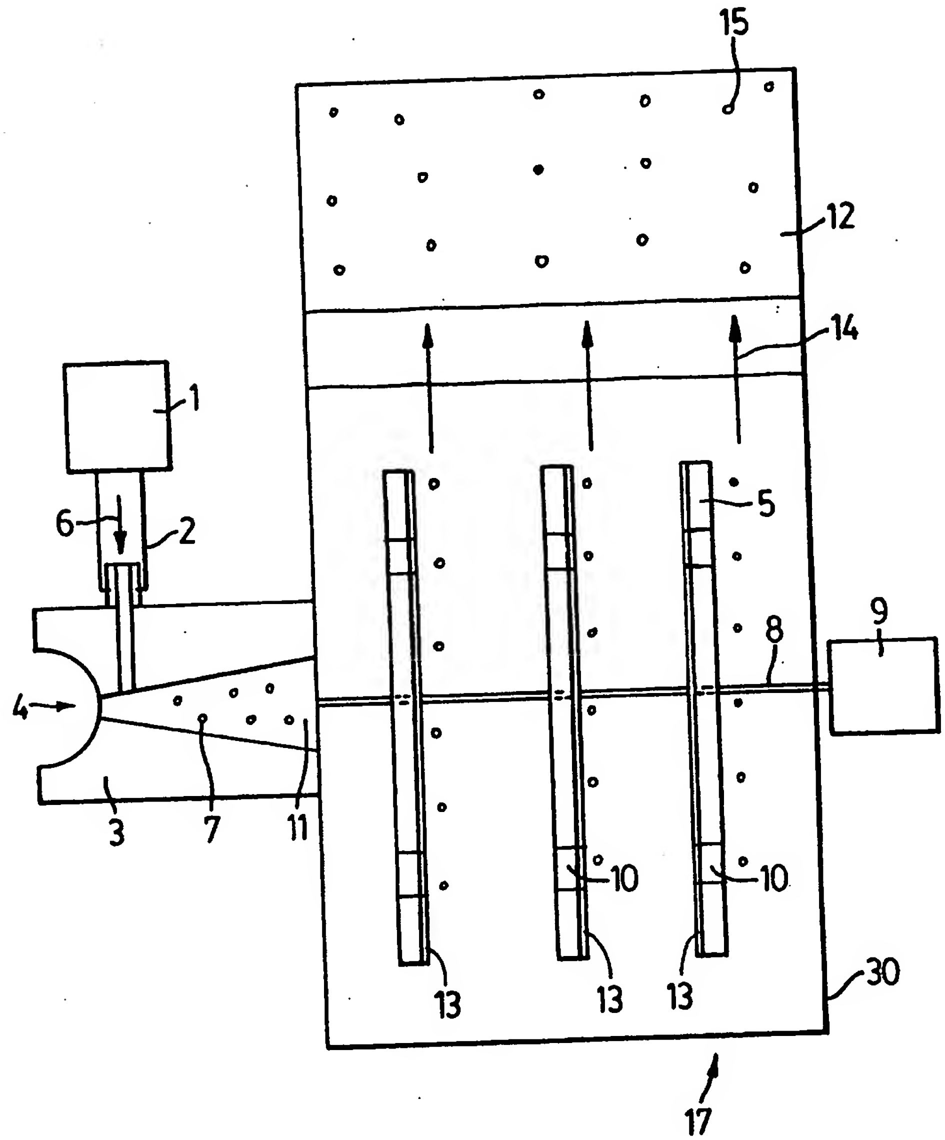


FIG. 1

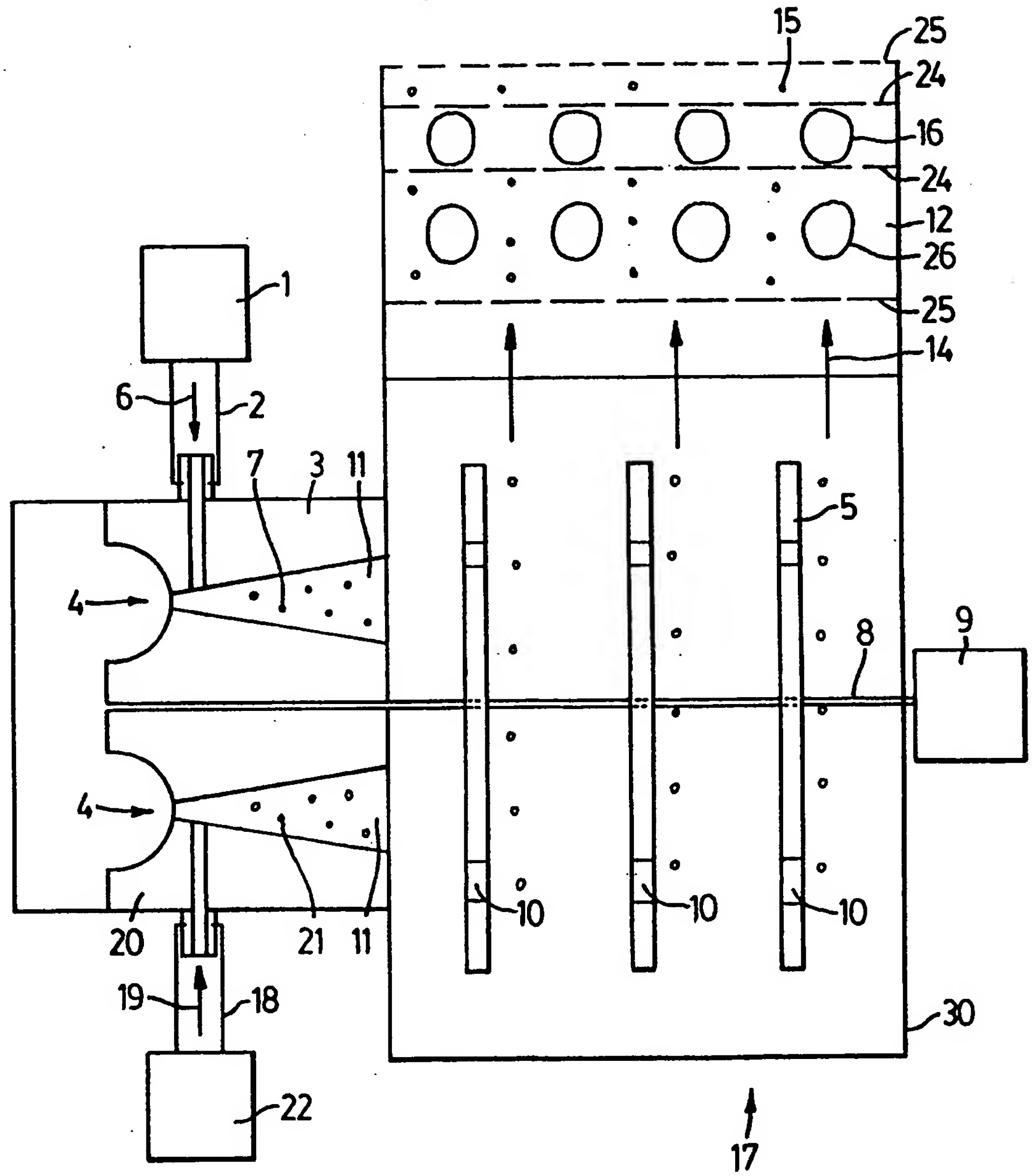

15
25
24
16
24
12
26
25
14
1
6
2
7
3
11
5
4
9
8
4
10
10
10
20
21
11
19
18
30
22
17

FIG. 2